Investigation of ultrashort pulse dispersion through a non-linear microscope

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The dispersive optics within a microscope combined with the intrinsic broad frequency bandwidth of ultrashort pulse mean that pulses entering a microscope can differ greatly from those that are incident upon the sample plane. Further problems arise when we consider that the dispersion from the objective lens is dependent upon the alignment of the incident pulse. This means that the pulse duration and thus efficiency of the non-linear process will not be constant throughout a scanned image. To investigate this effect we perform a complete study of how ultrashort pulses, at the sample plane of a non-linear microscope, change with differing scanning positions. To do that, full pulse characterisation (amplitude and phase) is performed as a function of incident angle in the objective lens.

Despite the maturity characterisation techniques there has been great difficulty in obtaining accurate pulse measurements at the focal plane of high numerical objective lens. In this work we overcome previous problems by using two recently introduced techniques. Firstly we utilise a data processing procedure to successfully transform a collinear-FROG (CFROG) trace into a standard non-collinear FROG trace [1]. Secondly, starch is placed at the sample plane of the microscope to act as a broadband, polarisation insensitive non-linear medium [2]. Figure 1 outlines the experimental arrangement used.

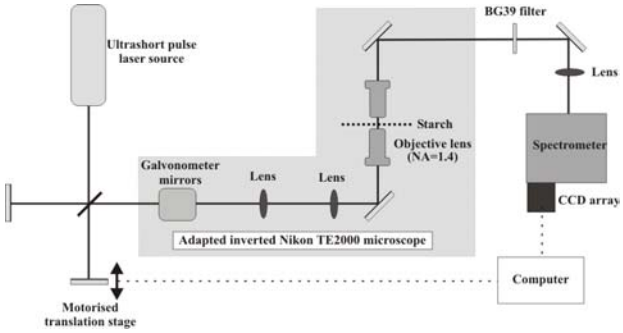

Figure 1. Schematic diagram of the optical arrangement

The pulses from five separate scanning positions were characterised. The first measurement was taken with the pulses travelling down the centre of the objective lens, a coordinate of (0,0), where the coordinates refer to the voltages applied to x and y galvanometer mirrors respectively. We chose the other four measurements to be radially symmetric. Figure 2a plots together the spectral phase of all of five measurements and Figure 2b plots the full width half maximum of each retrieved pulse with respect to scan position. There are a number of interesting and important points to take from these results. Firstly, the radially symmetric positions give similar, but not identical phase profiles. The reason for this slight difference is highlighted in Figure 3b where the predicted quadratic response to axial position is observed. Crucially however, the minimum point is not at 0V but is in fact close to ~-0.2V. This gives the clear indication of a very slight misalignment of the beam sensitivity of the measurements as well as providing a useful way of finding small, systematic errors in the alignment of the microscope. Further exploration of the pulse propagation through the microscope as a function of input polarisation will be presented.

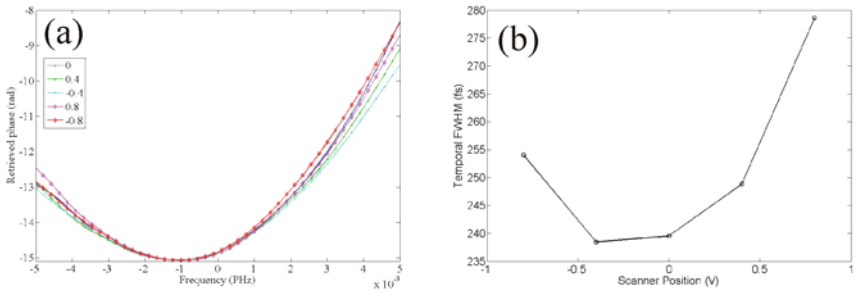

Figure 2. (a) The spectral phases and (b) Pulse durations of retrieved pulses at different scanning positions.

In conclusion we have investigated the characteristics of ultrashort pulses as they propagate through a microscope. We have observed the dispersive symmetry of the objective lens by characterising the pulses at the sample plane and showing how the amplitude and the phase increase as the pulses are scanned away from the centre of the lens. Importantly, since starch has a very large phase matching bandwidth, the technique outlined here can be applied to even shorter pulses (> 15fs) where the dispersive effects will be far more dramatic.

References

[1] I. Amat-Roldán et al. Opt. Express, **12**, 1169 (2004)
[2] I. Amat-Roldán et al. Opt. Lett., **29,** 2822 (2004)